# Design Models for the Development of Helium-Carbon Sorption Cryocoolers

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We have developed models for predicting the performance of helium-based Joule-Thomson continuous-flow cryocoolers using charcoal-pumped sorption compressors. The models take as inputs the number of compressors, desired heat-lift, cold tip temperature, and available precooling temperature and provide design parameters as outputs. Future laboratory development will be used to verify and improve the models. We will present a preliminary design for a two-stage vibration-free cryocooler that is being proposed as part of a mid-infrared camera on NASA's Next Generation Space Telescope. Model predictions show that a 10 mW helium-carbon cryocooler with a base temperature of 5.5 K will reject less than 650 mW at 18 K. The total input power to the helium-carbon stage is 650 mW. These models, which run in MathCad and Microsoft Excel, can be coupled to similar models for hydrogen sorption coolers to give designs for 2-stage vibration-free cryocoolers that provide cooling from ~50 K to 4 K.

*This research was carried out by the Jet Propulsion Laboratory, California Institute of Technology under a contract with the National Aeronautics and Space Administration.
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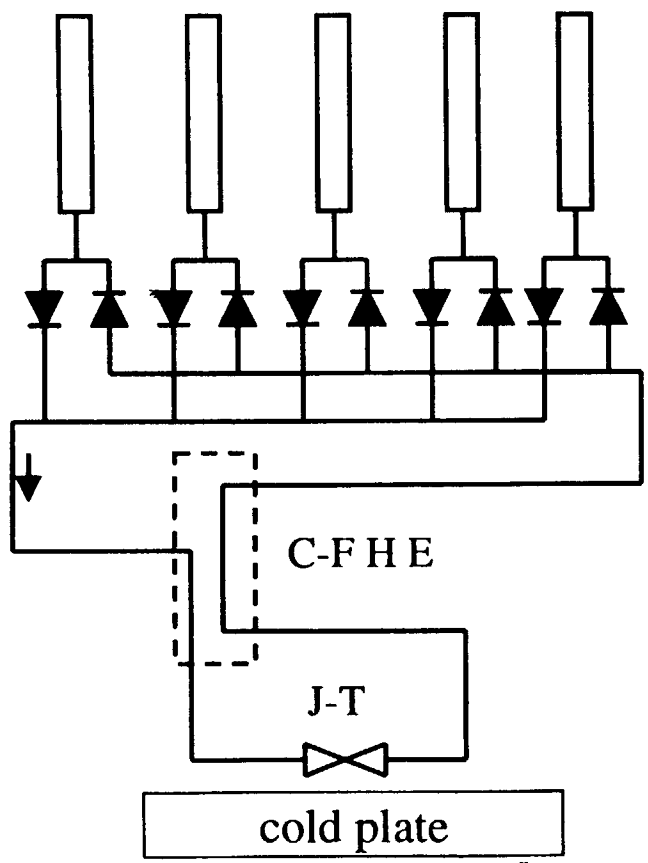
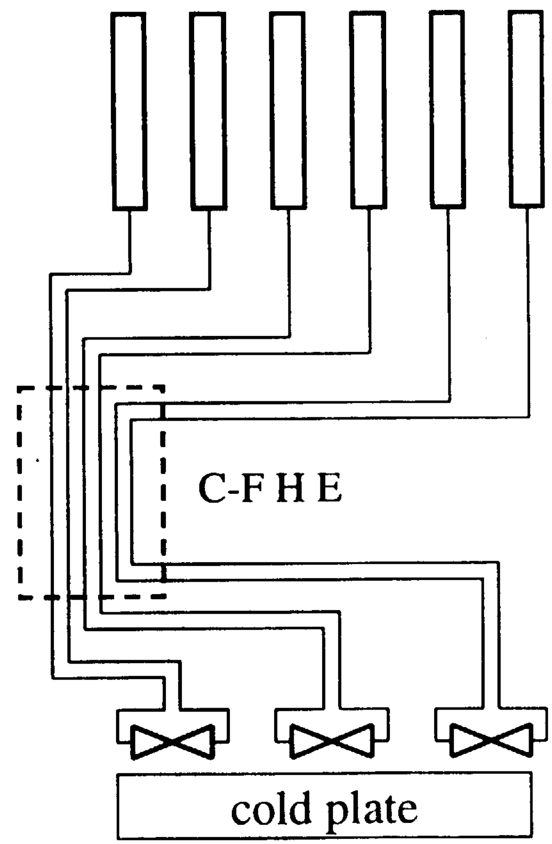
# Implementation of continuous cooling

Single J-T with check-valves




Multiple bi-directional J-Ts



# Helium-Carbon cooler design model

## model inputs

No. of compressor elements
cycle time
precooling temperature(s)
maximum compressor temperature
desorption and adsorption pressures
required cold plate temperature
required power lift
heat exchanger efficiency
materials properties of charcoal and container
allowable pressure drops in tubing
safety margins in pressure and temperature
heater electrical properties
length of J-T constriction

## model outputs

charcoal mass required
optimized dimensions of compressor elements
container mass
required heat rejection at precooler
efficiency of system
total mass of compressor elements
required C-F mechanical configuration
diameter of J-T constriction
heat switch parameters (for Helium gas-gap)

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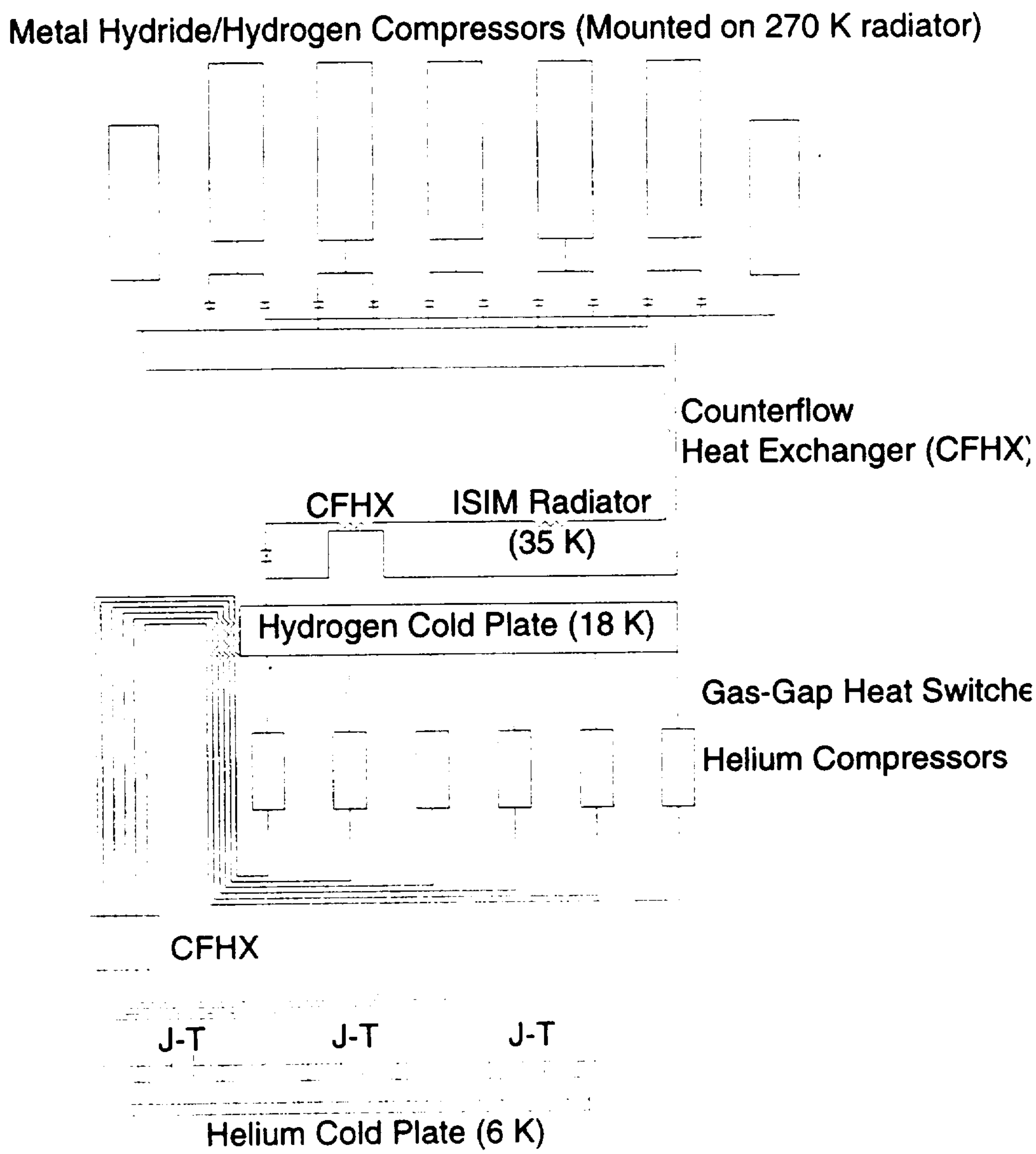
Basis of design model:

employs GasPak code from NIST, coupled to Excel spreadsheet to find enthalpy of Helium gas

charcoal properties from Duband, fits to Dubinin sorption model

either set of properties can be replaced by data in tabular or functional form

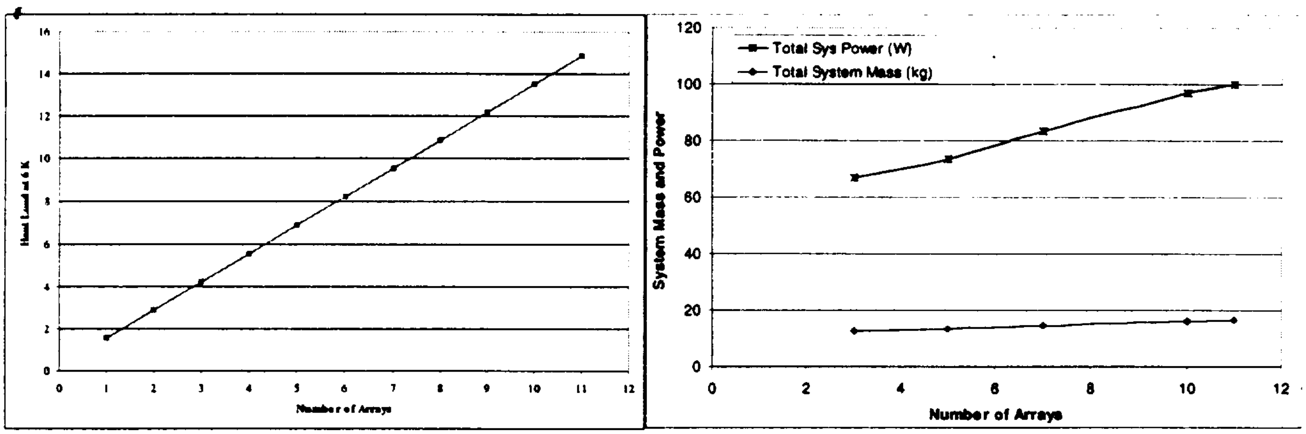
**Proposed Design for NGST 2-stage sorption cooler**



## Model predictions for NGST 2-stage system performance

He-Carbon performance from design models

H2--metal hydride performance from similar models and scaling of Planck coolers




A) The heat lift required at 6 K as a function of the number of detector arrays.
B) the total system mass and power as a function of the number of detector arrays.

Table 2. Cooler System Properties for Various 6 K Cooling Loads

| Heat Lift At 6 K (W) | Charcoal Input Power (W) (at 18 K) | Charcoal Sys Mass (kg) | Hydride Input power (W) (at 270 K) | Hydride System Mass (kg) | Total System Power (W) | Total System Mass (kg) | Passive Cooling requirements (W) At 35 K | At 270 K |
|---|---|---|---|---|---|---|---|---|
| 0.005 | 0.43 | .56 | 66.4 | 12 | 66.8 | 12.6 | 0.44 | 66.4 |
| 0.007 | 0.58 | .71 | 72.9 | 12.7 | 73.5 | 13.4 | 0.59 | 72.9 |
| 0.010 | 0.81 | .95 | 82.6 | 13.7 | 83.4 | 14.6 | 0.82 | 82.6 |
| 0.014 | 1.12 | 1.27 | 95.6 | 15.1 | 96.7 | 16.4 | 1.13 | 95.6 |
| 0.015 | 1.20 | 1.34 | 98.9 | 15.4 | 100.1 | 16.7 | 1.21 | 98.9 |